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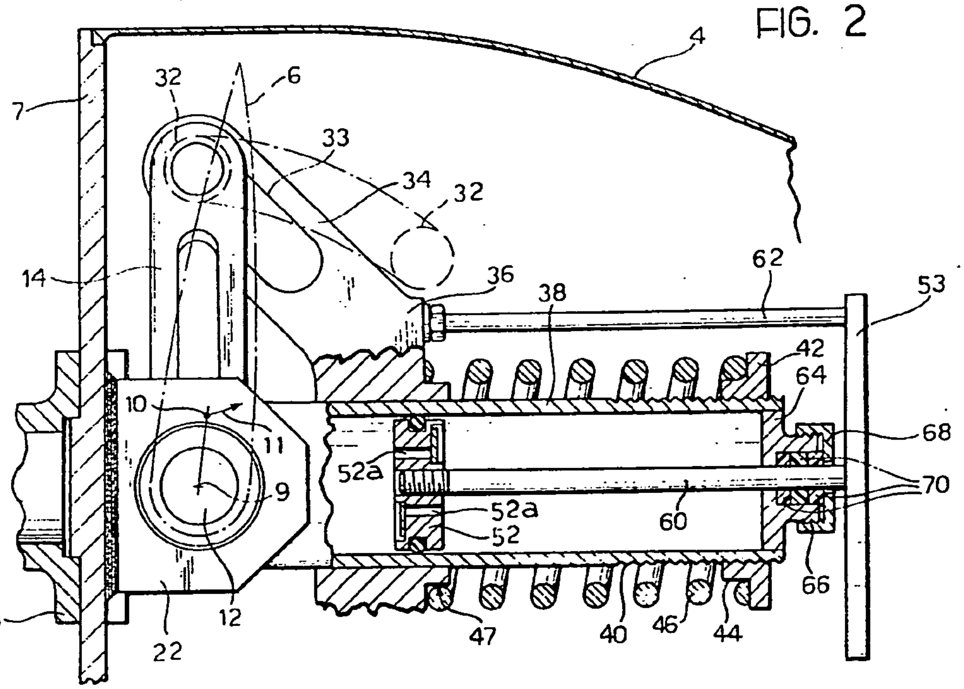
(54) Pitch Regulation Device for the Rotor Blades of a Wind Motor

(57) A device for regulating the pitch of the rotor blades (6) of a wind motor automatically in response to high wind loads on the blades includes a respective crank lever (14) attached to the shaft (12) of each variable pitch blade (6) and connected through a cam linkage (32, 33) to an arm (34) of an axially displaceable collar (36) which is loaded by a thrust spring (46). A piston (52) is connected to the collar and slides within a cylinder (38) to dampen vibration of the blades about their pitch axes.

FIG. 2



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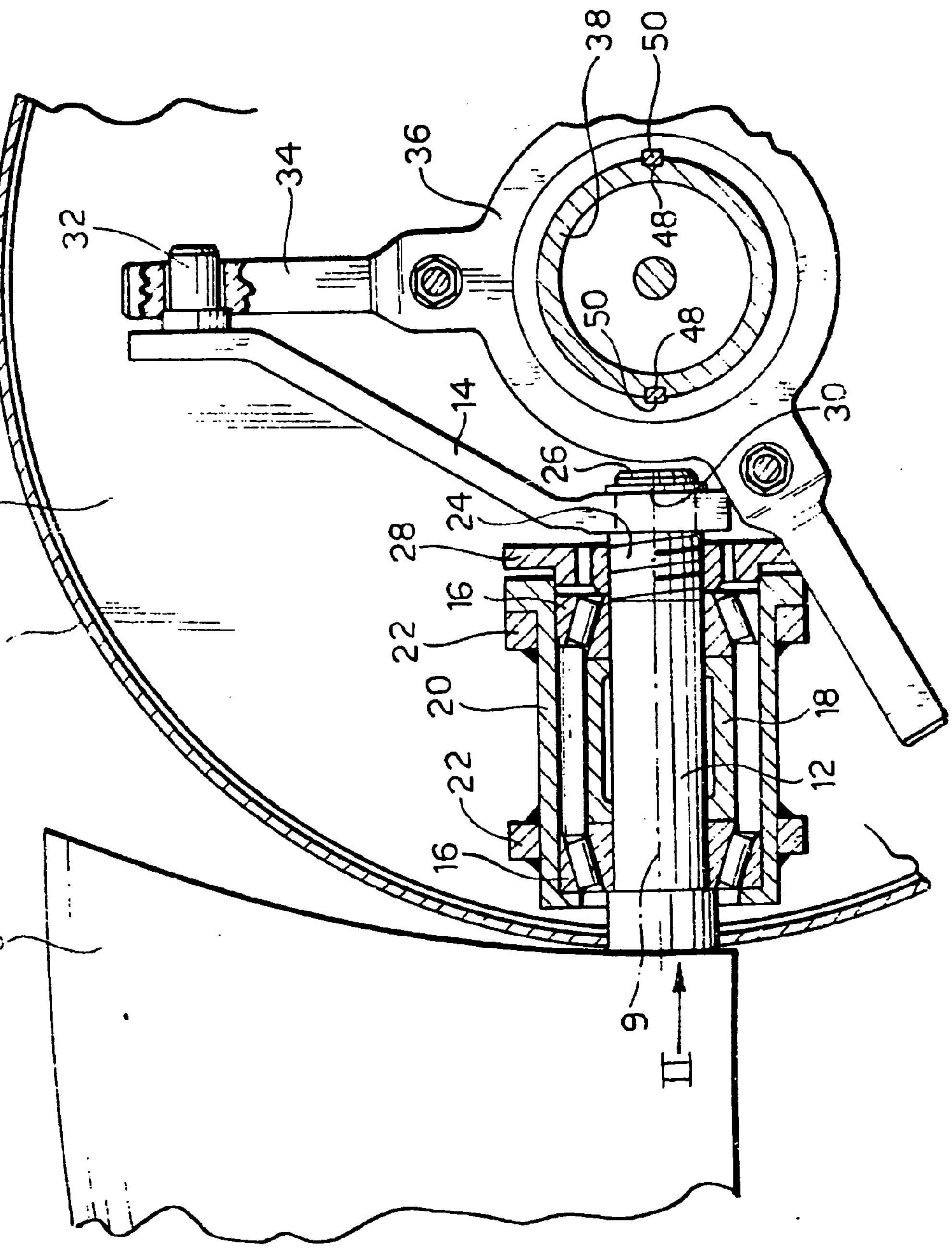

FIG. 1

FIG. 2

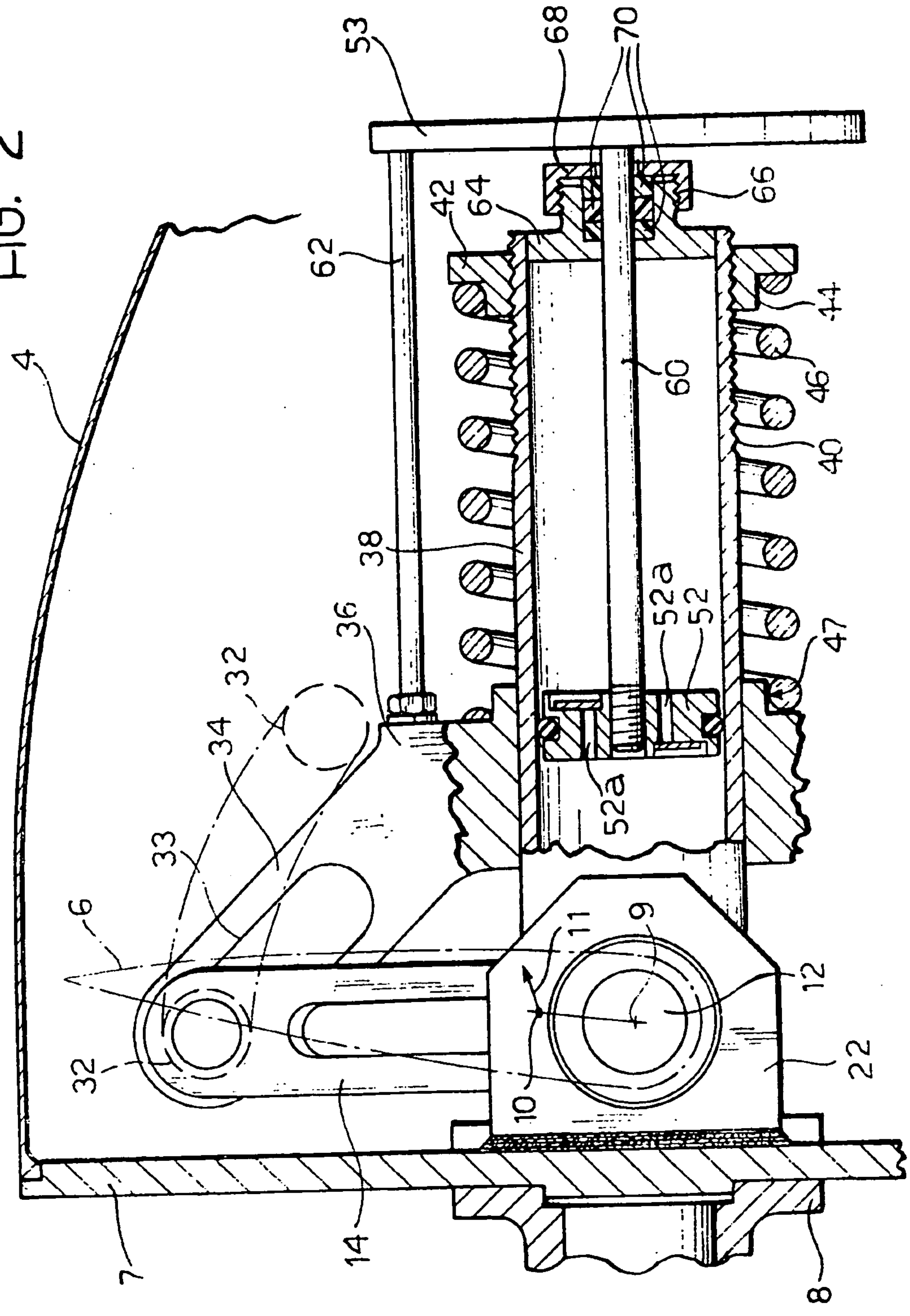

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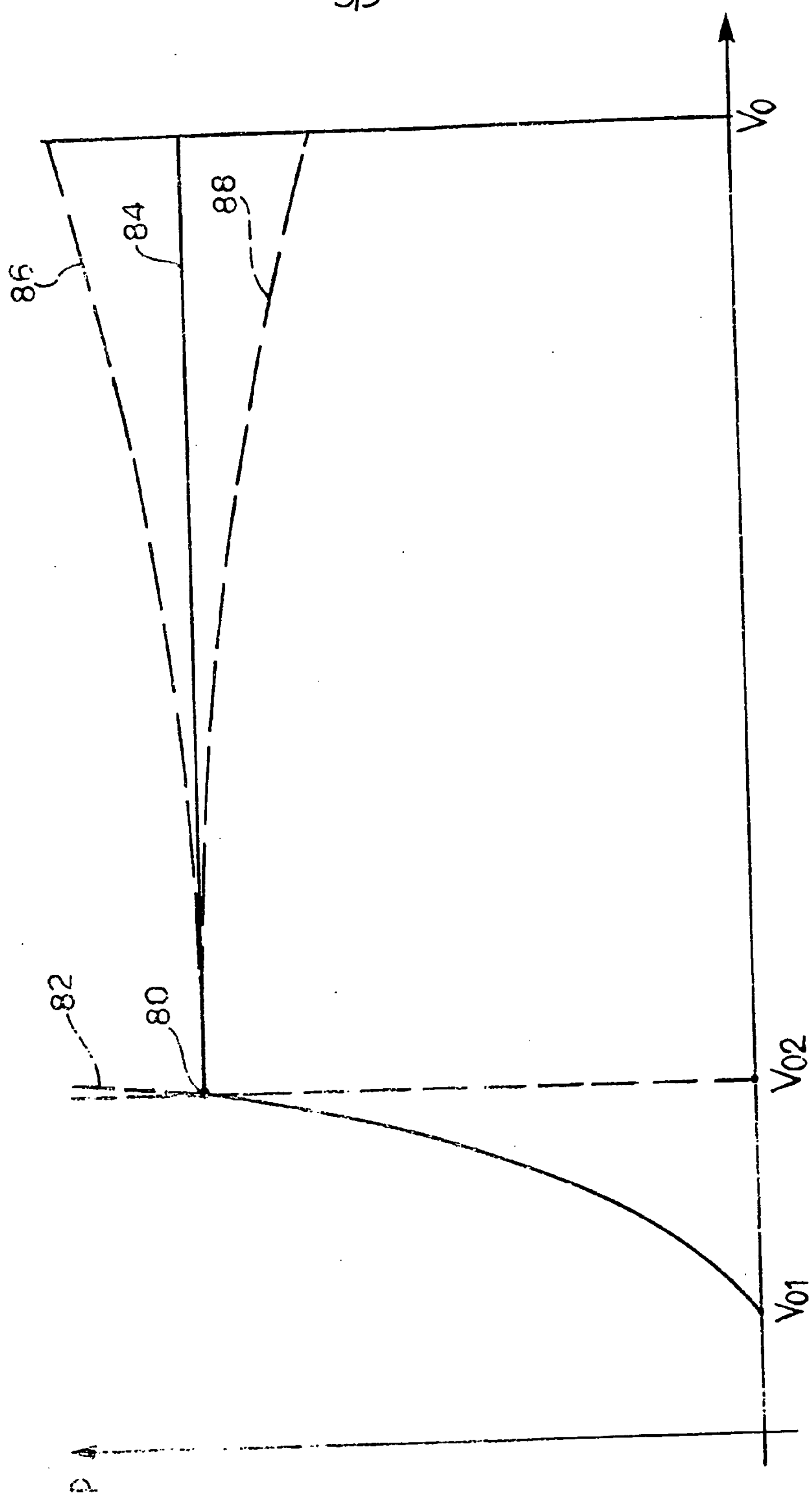
FIG. 3



SPECIFICATION

Pitch Regulation Device for the Rotor Blades of a Wind Motor

The present invention relates to a device for the regulation of the pitch of the rotor blades of a wind motor.

It is known that the power delivered by a wind motor with fixed-pitch rotor blades increases in proportion to the cube of the wind speed, while the forces acting on the blades increase in proportion to the square of the wind speed.

It therefore becomes necessary to protect the wind motor from damage when the wind speed exceeds a predetermined magnitude. Indeed, the situation could arise where the forces acting on the rotor blades, and the power absorbed by the motor, reached excessive values, resulting in damage to or even destruction of the motor and mechanisms which may be connected to it.

It is a known practice in the field of wind motors to protect the motor by appropriate variation of the pitch of the rotor blades. The blade pitch can then be adjusted so that the forces acting upon and the power absorbed by the motor are regulated in such a way as not to reach destructive limits.

Such pitch variation is generally effected by attaching to the motor a device for varying the pitch of the rotor blades. Unfortunately, known devices for the variation of the blade pitch tend to be complex and expensive on account of their large number of component parts.

An object of the present invention is to provide a device for the regulation of the pitch of the rotor blades of a wind motor which is of simple construction and which affords good control of the power delivered by the motor.

According to the invention there is provided a pitch regulation device for a rotor of a wind motor having blades which are rotatable about their longitudinal pitch axes to vary the pitch of the blades, characterised in that an axially displaceable element is arranged for displacement along the axis of the rotor, the said element having an arm corresponding to each rotor blade, each said arm being connected by means of a cam linkage to a crank lever connected to the associated rotor blade to effect axial displacement of the said element upon rotation of the blade about its pitch axis, and resilient means acting upon said element with an axial force which opposes changes in the blade pitch resulting from the wind force on the blade in use of the rotor.

The device of the present invention has the advantage of simple construction, and the cam linkage and resilient means can readily be selected, or in some embodiments, adjusted, to give an automatic adjustment of blade pitch in a sense to reduce the blade loading when the wind force on the blades exceeds a predetermined limit, thereby avoiding overloading of the rotor or the motor of which it forms a part.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a front elevation, partly in section, of part of a device according to one embodiment of the invention;

Figure 2 is a diagrammatic partly cut-away side view of part of the device, partly in section, viewed in the direction of the arrow II in Figure 1, and

Figure 3 illustrates graphically the power delivered by the motor as a function of the wind speed, for different blade pitch angles.

Referring to Figures 1 and 2, reference numeral 4 indicates part of a rotor hub spinner of aerodynamic form designed for the protection of the wind motor from the wind. The hub spinner 4 is constructed of plastics or some other suitable material. The rotor hub supports a number of rotor blades 6 arranged at equal angular intervals around the axis of the rotor, there being three such blades 6 in the illustrated embodiment, only one of which is shown. The rotor hub also includes a flat hub disc 7 to which the downstream end of the spinner 4 is attached, the disc 7 being fixed to one end of a rotor shaft 8.

The pitch-varying mechanism associated with one rotor blade 6 will be described, it being understood that an identical mechanism is associated with the other blades 6.

The pitch axis 9 of the illustrated blade 6 is positioned in relation to the centre 10 of the aerodynamic thrust 11 on the blade 6 (shown in ghost outline in Figure 2) in such a way that this thrust exerts a moment about the axis 9 in the sense which tends to increase the pitch of the blade 6.

The centrifugal forces acting on the blade 6 are balanced by known means, for example by counterweights (not shown).

The blade 6 is supported by a shaft 12 which is coaxial with the pitch axis 9 and which traverses the spinner 4. The shaft 12 is supported by two bearings 16 between which a spacer element 18 is arranged. The bearings 16 are housed within a bush 20 which is fixed to the hub disc 7 by means of a pair of fixing elements 22 welded to the said disc 7.

At its end remote from the blade 6 the shaft 12 has a threaded portion 24 and a reduced diameter inner end portion 26. A ring nut 28 is screwed onto the threaded portion 24 so that the end faces of the bearings 16 are thrust axially against the spacer element 18.

A crank lever 14 is fixed to the reduced diameter end portion 26 of the shaft 12, the lever 14 being retained on the said end portion by a split ring 30. The said crank lever 14 is keyed to the shaft 12 so as to be fixed non-rotatably to it.

A cam-follower roller 32 is carried at the free end of the crank lever 14 opposite the shaft 12. The roller 32 is movable along a suitably profiled cam slot 33 formed in a respective one of a number of (in this case, three) arms 34 arranged at equal angular intervals and projecting outwardly from an annular collar 36. In the illustrated embodiment the three arms 34 are

arranged at 120° to one another and have identical cam slot profiles.

The arm 34 may be provided with an external cam surface or an alternative form of cam instead of the cam slot 33. For example, a cam may be fixed to the arm 34 in a removable manner, by means of screws for example. Such an arrangement has the advantage that when it is wished to change the motion-transmitting characteristics of the cam it may suffice simply to substitute a cam of appropriate profile for the existing cam.

In a further alternative arrangement the positions of the roller 32 and the cam slot 33 on the crank lever 14 and on arm 34 respectively may be reversed, so that the roller 32 is carried by the arm 34 and the cam slot 33, or other equivalent cam, is formed or carried on the lever, 14. Moreover, a sliding cam follower element may cooperate with the cam instead of the roller 32.

The annular collar 36 is slidable axially on a hollow cylinder 38 coaxial with the rotor axis. An end section of the cylinder 38 is provided with an external screwthread 40 on which a ring nut 42 is screwed. The cylinder 38 is fixed to the rotor hub disc 7. The ring nut 42 has a stepped external surface with two different diameters, the surface 44 of smaller diameter being located within one end of a helical thrust spring 46 which abuts the shoulder formed between the two different diameter surfaces of the ring nut 42, the other end of the spring 46 engaging an annular shoulder 47 formed on the flange 36. The thrust exerted by the spring 46 is adjustable by screw-adjustment of the position of the ring nut 42 on the screw-thread 40 of the cylinder 38.

The cylinder 38 is formed in its external surface with a number of (in this case, two) axially extending channels 48 in which respective splines 50 are seated, to key the collar 36 to the cylinder 38 while allowing axial sliding movement of the collar 36 on the cylinder 38.

A piston 52 is sealingly slidable within the hollow cylinder 38. The piston 52 is traversed by at least two holes 52*a* of different diameters, each provided with a directional valve, for the purpose of damping mechanical vibration of the associated blade 6 about its pivoting axis 9. The cylinder 38 and piston 52 thus act as a dashpot. The piston 52 is connected to the annular collar 36 by means of a disc 53 connected to the piston 52 by a piston rod 60 and to the collar 36 by means of an external rod 62. The cylinder 38 has an end wall 64 adjacent the disc 53 through which the piston rod 60 passes, with suitable seating. An annular sealing cap 68 is screwed onto a threaded axial projection 66 of the cap 68. Respective annular grooves are formed in the end wall 64 and in the cap 68 for the seating of respective resilient sealing rings 70.

The interior of the hollow cylinder 38 is filled with fluid which damps movement of the piston 52 within the cylinder 38. This fluid is preferably air, so that periodic topping up or replenishment of the cylinder 35 is unnecessary.

The device is preferably designed to operate according to the working characteristics shown graphically in Figure 3, in which the wind speed V_0 is represented on the abscissa and the power P delivered by the wind motor is represented on the ordinate.

V_{01} is the starting up wind speed at which the wind motor starts to turn and V_{02} is the "cut-in" wind speed at which the rotor blade pitch regulation begins to operate: between the winds speeds V_{01} and V_{02} the wind motor operates with the rotor blades at fixed pitch. At the point indicated by 80, at the "cut-in" wind speed V_{02}, the power delivered by the motor is rising steeply according to the curve 82. To avoid rapid increase of the power delivered beyond the point 80, which could result in damage to the motor, the power is regulated as a function of the wind speed V_0 above the wind speed V_{02}. The regulation may be according to the line 84 (constant power) or the curves 86 and 88, according to choice of the wind motor designer. The precise relationship between the delivered power P and wind speed V_0 (for example, curve 84, 86 or 88) depends primarily on the profiles of the cam slots 33 or equivalent cams and secondarily on the loading of the springs 46 and the geometry of the pitch-varying motion transmitting mechanism of each rotor blade.

The greater the radially inward inclination of the axis of the profile of the cam slot 33 in relation to the circular arc described by the centre of the roller 32 as the pitch of the blade 6 (indicated partially in chain-dotted outline in Figure 2) changes, the greater will be the deflection of the spring 46 for a given rotation of the blade 6 about its pitch axis 9 and the greater, therefore, the reaction torque exerted by the spring 46 on the shaft 12. Thus the curve 86 corresponding to increasing power P with increasing wind speed V_0 above the speed V_{02} corresponds to a cam slot 33 having the greatest radially inward development.

For each of the rotor blades 6 of the wind motor there will be a corresponding support shaft 12 and associated bearings on the hub disc 7, a crank lever 14, a cam slot 33 or equivalent cam and a respective arm 34 of the collar 36 connected to the crank lever 14 as described above. A respective connecting rod 62 will be provided for each blade, connecting the movable annular collar 36 to the disc 53 and, *via* the rod 60, to the piston 52, which is common to all the blades. The operation of the illustrated pitch-regulating device according to the invention will now be described.

When the motor is at rest the spring 46 presses against annular shoulder 47 of the collar 36 which in turn, through the interengaging cam slot 33 and roller 32, the associated crank lever 14 and the respective shaft 12, maintains the blade 6 in the position of minimum pitch angle (or fine pitch) in which the blade operates, at low wind speeds between V_{01} and V_{02} (Figure 3), effectively with fixed pitch. Thus when the rotor is

driven by wind at a speed below V_{02} the aerodynamic force 11 acting on the blade 6 is insufficient to overcome, through the shaft 12, the lever 14, the roller 32, the cam slot 33 and the collar 36, the thrust exerted on the collar 36 by the spring 46, and the blade 6 remains in the initial position shown in Figures 1 and 2.

As the wind speed increases, the aerodynamic force on the blade 6 increases until, when the wind speed reaches V_{02}, the motion-transmitting linkage overcomes the initial thrust of the spring 46. The blade 6 is then rotated about its axis 9 in the direction of increasing the pitch angle, displacing the collar 46 to an equilibrium position, corresponding to a predetermined blade pitch angle for each wind speed, in which the compression of the spring 46 balances the force exerted on the collar 36 by the blades 6.

The axial displacement of the collar 36 on the cylinder 38 also displaces the piston 52 which is connected to the collar 36 through the rods 62, disc 53 and rod 60. This displacement of the piston 52 in the cylinder 38 has a vibration-damping effect by virtue of fluid flow through the holes 52*a* and associated unidirectional flow valves in the piston 52. This damps the vibrations which would occur through the intertia of the blades 6 and the mechanism connected to the blades when the pitch of the blades is changed.

The angular equilibrium position, that is, the pitch of the blades, corresponding to a given wind speed, depends on the cam mechanism associated with the blades and on the initial thrust exerted by the spring 46. Both the cams and the springs can readily be interchanged to predetermine the characteristics of the pitch regulating device.

The pitch regulating device of the present invention may be used on different types of wind motor, including those in which the rotors are mounted on the windward side of a support pylon and those in which the rotors are mounted on the leeward side of a support pylon. Conversion of the rotor from a windward to a leeward mounting position simply entails rotation of the blades in their rest or fine pitch setting through 180° about their pitch axes.

Claims

1. A pitch regulation device for a bladed rotor of a wind motor having blades which are rotatable about their longitudinal pitch axes to vary the pitch of the blades, the device comprising an axially displaceable element arranged for displacement along the axis of the rotor, the said element having an arm corresponding to each rotor blade, each said arm being connected by means of a cam linkage to a crank lever connected to the associated rotor blade to effect axial displacement of the said element upon rotation of the blade about its pitch axis, and resilient means acting upon said element with an axial force which opposes changes in the blade pitch resulting from the wind force on the blade in use of the rotor, so that the blades can adopt an equilibrium blade pitch when acted upon by a wind at a speed at which the device is operative.

2. A device according to claim 1, in which each said cam linkage is formed by a cam follower element carried by said crank lever and a cam on the said arm engaged by said cam follower element.

3. A device according to Claim 1, in which each said cam linkage is formed by a cam follower element carried by the said arm and a cam on the said crank lever engaged by the cam follower element.

4. A device according to claim 2 or claim 3, in which each cam follower element comprises a roller.

5. A device according to claim 2 or claim 3, in which each cam follower element comprises a sliding element.

6. A device according to any one of claims 2 to 5, in which each cam is formed by a slot in which the associated cam follower element engages.

7. A device according to any one of claims 2 to 5, in which each cam is formed by an external edge or surface on the part which carries the cam.

8. A device according to any one of claims 2 to 7, in which each cam is formed on an element which is removably secured to the part which carries the cam.

9. A device according to any one of the preceding claims, in which the longitudinal pitch axis of each blade is positioned in relation to the centre of aerodynamic thrust on the blade in use of the rotor in such a way that the moment exerted on the blade by this aerodynamic thrust about said axis is in a sense to increase the pitch of said blade.

10. A device according to any one of the preceding claims, in which the axially displaceable element is connected mechanically to a damper device for damping rotational oscillations of the blades about their pitch axes.

11. A device according to Claim 10, in which the damper device comprises a cylinder fixed to the rotor and a piston which is slidable within the cylinder and which incorporates flow restricting passages, the piston being connected externally of the cylinder to the axially displaceable element.

12. A device according to claim 11, in which the axially displaceable element comprises a collar which surrounds the cylinder and is keyed to the latter for longitudinal and non-rotational displacement relative to the cylinder.

13. A pitch regulation device for a variable-pitch bladed rotor of a wind motor, substantially as herein described with reference to and as shown in the accompanying drawings.

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